SPACE SCIENCES LABORATORY

AN INTEGRATED STUDY OF EARTH RESOURCES IN THE STATE OF CALIFORNIA BASED ON SKYLAB AND SUPPORTING AIRCRAFT DATA

A report of work done by scientists on 2 campuses of the University of California (Berkeley and Riverside) and of the California office of the Bureau of Land Management under NASA Contract No. NAS 2-7562

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AN INTEGRATED STUDY OF EARTH RESOURCES IN THE STATE OF CALIFORNIA BASED ON SKYLAB AND SUPPORTING AIRCRAFT DATA (EPN NO. 454)

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Chapter 1 — SKYLAB DATA AS AN AID TO RESOURCE MANAGEMENT IN NORTHERN CALIFORNIA (EPN NO. 454, TASK 4.3)

Chapter 2 — USE OF SKYLAB DATA TO ASSESS AND MONITOR CHANGE IN THE SOUTHERN CALIFORNIA ENVIRONMENT (EPN NO. 454, TASK 4.6)

and

THE CALIFORNIA DESERT PROGRAM -- RESOURCE INVENTORY AND ANALYSIS (EPN NO. 454, TASK 5.0)

Chapter 1

SKYLAB DATA AS AN AID TO RESOURCE MANAGEMENT IN NORTHERN CALIFORNIA (EPN NO. 454, TASK 4.3)

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1.1 INTRODUCTION

The wise management of a wildland area rests largely on the accuracy and timeliness of inventory information of the available resources and a basic description of the wildland area. In the present study Skylab S190 images and S192 digital tapes are being utilized for range management, forestry, watershed management and forest fire fuel mapping in an effort to provide useful and necessary information to the resource manager. In addition, high altitude and low altitude aerial imagery as well as ground data are serving as integral components of the inventory. Within the Feather River watershed, a multiresource study area has been selected and an initial stratification completed. With the aid of input from interested user groups, appropriate classification schemes have been selected for use with the CALSCAN* classification program. This integration of photo interpretation and computer discriminant analysis techniques, combined with the input from user groups should provide the quality of information necessary at both optimum time and cost.

1.2 WORK PERFORMED DURING THE PERIOD COVERED BY THIS REPORT

1.2.1 Selection of Study Area

Within the Feather River watershed four 15-minute USGS quadrangles were selected for intensive analysis. Bucks Lake, Mooreville Ridge, Paradise and Pulga quads, encompassing an area of approximately 590,000 acres, were selected for the following reasons: (1) these areas are

*CALSCAN is the CRSR version of the LARS-Purdue pattern recognition program adapted to the CDC 6600/7600 system at the University of California, Berkeley.

imaged on both Skylab S190 color and color infrared photography and Skylab S192 digital tapes, (2) they constitute the only relatively cloud free part of the Feather River watershed imaged by both data systems, (3) previous related research activities within these study areas have provided pertinent background information, (4) excellent quality high altitude imagery is available for stratification, identification of classes, and training cell delineation (Skylab RB57F support Missions 239 flown June, 1973, and 248 flown August and September, 1973, as well as other high altitude flights have provided imagery at scales 1:60,000 and 1:120,000), and (5) the quads form a transect from the range grassland and valley front of the Sacramento Valley, across the foothills of the Sierra Nevada, to the high Sierra crest; this transect crosses significant vegetation/terrain boundaries and provides significant examples of the various timber, watershed, fuel and range classes under investigation.

1.2.2 Stratification

Stratification of the four-quadrangle study area on the high altitude Skylab support imagery (June, 1973) has been completed. The initial step in the stratification procedure was to identify the significant strata which would lead to the most effective and least costly classification in relation to the four disciplines being studied: the Forest, Range and Watershed resources, and Fuel typing. After a comparison of the parameters necessary to be representative of each discipline, stratification proceeded, grouping the parameters of common interest: (1) Bare soil/bare rock, (2) Chaparral, (3) Grassland, (4) Conifer/Broadleaf forest, and (5) Water. The effective areas on the 9 x 9-inch color infrared transparencies (scale 1:120,000) were delineated and the 590,000 acres were stratified using stereo viewing. The larger scale 1:60,000 color infrared transparencies enabled checking the stratification boundaries. In addition, the larger scale images will be used to accurately locate the training cells for input to the CALSCAN classification program.

1.2.3 Identification of Significant Classes and Training

Significant classes have been identified and some training sets located on the high altitude photography. It has become apparent, however, that the significant classes that have been chosen will require two iterations for complete discriminant analysis classification for the four-quadrangle study area. The first iteration will have training cells for the vegetation resources of the area based on what is visible on high altitude aerial imagery now in hand. From the first set of classification results, a number of randomly selected samples for each class will be chosen and large scale high resolution 35 mm aerial photography by skilled photo interpreters will locate training cells for the CALSCAN system that will provide the more detailed analysis of the resources of the area, which have been specified by user agencies. Table 1.1 lists the selected significant classes (by strata) and

TABLE 1.1. CLASSES BY STRATA FOR DISCRIMINANT ANALYSIS OF THE FOUR QUADRANGLE STUDY AREA

Strata	Classes -- Iteration #1	Classes -- Iteration #2
Timber	Coniferous Forest by volume (gross) classes 1. less than 10,000 BD.FT./AC 2. 10,000-20,000 BD.FT./AC 3. greater than 20,000 BD.FT./AC	Volume by condition class
	Hardwoods	Riparian site hardwoods Dry site hardwoods Dry
Rangeland	Herbaceous	Perennial grass Perennial forbs Annuals (forbs and grasses) Meadow (grass, forbs, sedges, rushes) Marsh (fresh) Tundra Alpine fell fields
	Shrub	Chaparral Mountain Shrub Sagebrush
	Shrub Conversion	Shrub Conversion
Bare Ground	Rock	Granite Serpentine type
	Bare soil	Bare soil
Water	Water	Water

separates the classes to show the relationship between the first iteration and the second iteration. The results of the two CALSCAN classification runs will contain information that can be grouped to provide data for fuel mapping following the classes listed by strata in Table 1.2.

Because of the problems with "noise" on the S192 data, the first iteration discriminant analysis has not been completed and it is hoped that CRSR will soon be receiving relatively "noise"-free S192 data.

1.3 WORK PLANNED DURING THE NEXT REPORTING PERIOD

1.3.1 Extraction and Analysis of Training Area Data

Training areas for the vegetation types identified in Section 1.2.3 will be transferred to the multispectral scanner images and the data extracted, picture element-by-picture element, from the raw tape data. The raw data will then be subjected to intensive statistical analysis to determine the correlation between bands, separability of vegetation types, and adequacy of the training. Small areas will be run through the discriminant analysis to determine the adequacy of the training and if it is found to be inadequate, additional training will be undertaken. At this point, certain vegetation samples can be combined, if it is found that they constitute a natural vegetation type. This stage in the processing is very important because it determines how well the classifier will do in estimating the parameters of interest. It also reduces the cost of the overall processing if the number of classes can be reduced.

1.3.2 Classification of Study Area

The information generated in the above steps will next be combined with the entire area digital tapes, and the discriminant analysis will then be run. The stratification data will be used to supervise the discriminant analysis by specifying the training classes to be considered at each point in the image.

1.3.3 Definition of Sampling Unit and Sample Size (n)

The results of the discriminant analysis will next be applied to an intensive study to determine the optimum size of the ground sampling unit. The size of the sampling unit will be determined by the variation in the amount of resource of each type within the unit, the accuracy of the discriminant analysis, the photographic coverage of the low altitude aircraft imagery, and the amount of ground work that can be accomplished in one day by the field crew. These variables will all be used to determine the optimum width and length of these primary sampling units (PSU's). The difference between ground estimates and Skylab estimates of the resource within the sampling units will be used to determine the number of samples (n) that will be required to

TABLE 1.2. CLASSES BY STRATA FOR FUEL MAPPING

Strata	Classes to be Located
Timber	1. Thinned or partially cut with slash a) Coniferous slash with needles b) Hardwood slash or coniferous slash without needles 2. Open canopy with grass and herbaceous plants as the common ground fuel 3. Closed canopy (may be openings) Primary ground fuel of duff, litter, branchwood, tree boles. 4. 2/3 or greater area deciduous trees a) Dormant overstory -- leaf litter not compact b) Non-dormant overstory or leaf litter compacted by rain or snow 5. 1/3 of area or greater has coniferous trees a) Overstory mature (or over-mature, decadent) and heavy accumulation of branchwood, downed trees, duff, and litter b) Overstory immature (or mature) and only nominal accumulation of debris 1) Brush or reproduction < 1/3 of area 2) Brush or reproduction > 1/3 of area
Non-Timber (< 1/3 of area occupied by trees)*	1. Predominant fuel is grass, herbaceous plants, or mosses and lichens 2. Brush or reproduction > 1/3 of area 3. Dense chaparral $\geq$ 6 feet in height 4. Brush conversion areas (recently cut or thinned) 5. Conifer stand with heavy slash build-up (2/3 of area is slash) 6. Conifer stand with moderate slash build-up (1/3-2/3 of area is slash) 7. Conifer slash predominant fuel with foliage attached 8. Slash with foliage no longer attached

*Note: Stunted tree species and conifer reproduction are grouped with shrubs and called brush. Slash is not considered as brush.

complete an inventory to a specified level of accuracy and precision for each of the disciplines.

1.3.4 Estimation of Resource by Sampling Unit

A program known as "Break-up" will be used to divide the entire study area into the rectangular PSU's as defined in the previous step. For each of these PSU's there will be an estimate of each of the resources of interest within it, as provided by the discriminant analysis and the appropriate weighting factor for each of the classes present. The evaluations of the individual PSU's will be summed to provide the Skylab estimate of the resource for the entire study area. This initial estimate will be unique and extremely valuable in the further sampling design. Sampling procedures in general do not start with a data base as valuable or sophisticated as the Skylab discriminant analysis data will provide. The fact that we know something about every acre within the study area will allow us to sample at a much lower density than would be practical under a simple random sampling design.

After the area has been broken up into sampling units and they, in turn, have been evaluated for each of the resources of interest, certain of these sampling units will be selected for low altitude, large scale photography and subsequent ground sampling using a list sampling procedure (Langley, 1970). Samples will be selected independently for the timber inventory, the range inventory, the watershed inventory, and the fuel mapping. It is felt that probability sampling will be optimum for the timber and range inventories, while simple random sampling may be optimum for the watershed and fuel mapping. However, if it is found that values can be placed on fuel by hazard class or resistance to control, and to the watershed areas by their relative importance to the watershed, probability sampling will more than likely be used for these parameters, also.

1.3.5 Acquisition of Large Scale Photos

The flight lines selected in the previous step will be transferred to high flight photography. The PSU's will then be flown using a small camera system (e.g., 35 mm cameras) to acquire large scale photography. The high flight photographs will be used for navigational purposes in flying the flight lines. A camera of short focal length (24 mm) will be used to acquire small scale coverage of the entire flight line for location purposes. A camera of long focal length (200 mm) will be used to acquire large scale stereo samples of the flight line.

1.3.6 Interpretation of Large Scale Imagery

Detailed photo interpretation and photogrammetric measurements will be taken from the large scale imagery obtained in the previous step. For making the timber inventory, tree heights, crown diameters

and species composition will be used to estimate timber volume by species for the flight line. This will be done by interpreting the large scale photo plots obtained with the long lens camera system. In the range inventory, areal extent, species composition, and condition will be estimated from the imagery. In the watershed study, timber stand density, species composition, stand height, and condition will be interpreted. In the fuel mapping study, species composition, volume per unit area, live-to-dead ratio, stand age, and stand height are some of the photo interpretation and photogrammetric measurements that will be related to the ground data, as described below.

1.3.7 Ground Sampling

Each of the ground samples defined and selected in the photo interpretation stage will be visited. The parameters estimated on the photos will be measured on the ground for each of these plots. These ground measurements will be used to establish the mathematical and statistical relationship between the photo estimates and the ground estimates.

1.3.8 Comparison, Statistical Summary, and Estimation

In order to establish the validity of the above process and its information content, much time will be spent in analyzing the numerical data obtained at all stages. The sampling errors associated with the estimates will be established, the critical parameters will be identified, and the variance associated with the estimates of these parameters will be determined. The relationship between the ground and photo stage and also that between the photo and Skylab stage will be determined. Direct comparisons will then be made between photo interpretation results and Skylab results.

Sampling procedures are required in this study because there is not perfect correlation between ground, photo interpreter, and discriminant analysis estimates. Ultimately, if these estimates are perfectly correlated, no ground samples will be required. In a continuing effort to establish a perfect correlation, considerable attention will be paid to this step to determine where improvements can be made.

1.3.9 Multi-Dimensional Information Overlay ("MAPIT")

Twenty-one "thematic" maps of the upper Butte County area have been obtained from the California Department of Water Resources. These maps contain information on vegetation, ownership, soils, geology, water, and fire hazard. This information will be digitized and put in common register with the results of the Skylab image analysis. Comparisons will be made between the existing maps and the maps generated from the Skylab data. Where differences occur, the source of the difference will be investigated. Ultimately, however, these overlay maps and the Skylab data will be presented to the user agencies for their

evaluation and use. It is hoped that this information can be placed in the user's hands prior to the completion of the Skylab project so that their reaction and critical evaluation can be included in our final report.

Chapter 2

USE OF SKYLAB DATA TO ASSESS AND MONITOR CHANGE IN THE SOUTHERN CALIFORNIA ENVIRONMENT (EPN NO. 454, TASK 4.6)

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THE CALIFORNIA DESERT PROGRAM -- RESOURCE INVENTORY AND ANALYSIS (EPN NO. 454, TASK 5.0)

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2.1 INTRODUCTION

Skylab research accomplishments to date at the Riverside campus have been limited. Because of prevailing inclement weather over a significant portion of the test site during the Skylab pass, only marginally useful imagery has been received and analyzed to date. Research being accomplished focuses on studies in the Mojave Desert, along the Colorado River and the Delta, and in the Coachella-Imperial Trough. Abstracts of these studies follow under Section 2.2. This report is intended to suffice for both the University of California at Riverside and the Bureau of Land Management, Riverside.

2.2 WORK PERFORMED DURING THE PERIOD COVERED BY THIS REPORT

2.2.1 A Remotely Sensed Evalution of the Tectonic Controls Affecting Resource Distribution in a Portion of the Mojave Desert and Coachella-Imperial Trough, California

A map of the tectonic framework of the Mojave Desert north of San Bernardino was prepared during the spring and summer of 1973 using

Mission 164 and ERTS-1 imagery. Following the preparation of this map, a generalized stress-strain model was developed to explain the structural fabric of the area. The Skylab imagery will be used in conjunction with this model, and an evaluation of the tectonic controls which have affected the distribution of certain natural resources within the area will be made. Those resources of prime importance in this proposed project are groundwater and previously unexplored petroleum and/or mineral deposits.

This project will, therefore, utilize Skylab imagery in the assessment of resources and potential resources which might directly affect the economic sector of the environmental quality of the south-central Mojave Desert. Subsequently, the study will be expanded into the Coachella-Imperial Trough.

2.2.2 Colorado River Delta -- A Skylab Automatic Mapping Project

This task is an outgrowth of earlier interpretation of ERTS-1 imagery. It is the intent of this mapping project to expand and demonstrate a capability for automatically mapping a dynamic physical environment. The project is viewed as a method of exploiting existing and future acquisitions of sequential spacecraft imagery, i.e., ERTS and Skylab. Its purpose is to depict, using automatic computer mapping techniques, variations in surface forms as witnessed in the Colorado River Delta, the Sonoran Coast and Desert (Desierto del Altar) of Mexico, and the Gulf of California.

A classification system is being developed for the various landforms and water surface features identified in the area. Three separate generic classifications are requisite in order to adequately represent the three distinctly different environmental types found in the region: (1) the Coastal and Delta Landforms; (2) Immediate Shore Features; and (3) Offshore (water Features. To date, offshore tones only have been mapped and classified as it is extremely difficult to accurately interpret true water depths or actual subsurface features from the imagery. Tonal signatures were mapped from normal color Skylab imagery (2 June 1973). The completed map depicts only relative water depths in the Gulf and is indicative of only the visible color gradations recorded on the imagery.

Further correlations of the above water depth surrogates to existing bathymetric data are being conducted. Also water depth surrogates are being mapped from existing ERTS-1 imagery of the nearshore delta waters. These depth surrogates will then be incorporated into the automatic mapping system initiated previously and included into the correlation model of bathymetric data as developed above. Initial impressions obtained from cursory interpretation of the data indicate that actual water depths in the delta waters can be interpreted and mapped from Skylab and other spacecraft imagery.

Mapping of the geomorphic features of the Desierto del Altar is in progress but as yet these data have not been incorporated into the automatic mapping system.

2.2.3 Computer Projection of Lake Cahuilla Pleistocene Shorelines

Research has been initiated to attempt to accurately locate the Pleistocene shoreline of Lake Cahuilla. Lake Cahuilla was the Pleistocene Lake which was impounded in the Coachella-Imperial Trough. The graben is now partially filled by the Salton Sea. Extensive agricultural and tectonic activity in the trough has obliterated the shoreline of former Lake Cahuilla.

Automap programs will be adapted to allow projection of the Lake Cahuilla shoreline. Existing segments of relict shoreline will be used as control elevations. The shoreline will then be developed on existing topography by generating a surface for the lake at its maximum extent.

Another rationale for generating lake surfaces would be the input of estimated evaporation data to project various surface levels during the lake lowering. This aspect of the study will have application by archeologists to locate habitation sites and relict cultural features in the region. Also, evaporation inputs have application in attempting to model the Plio-Pleistocene environments of the region.

2.2.4 Areal Distribution of Relict and Active Cultural Features of the Northern Lanfair Valley and Surrounding Areas of California-Nevada

Within the study area a series of cultural features appears which exhibits characteristics of both relict and active cultural morphologies. These features are readily discernible from Skylab imagery. The degree of development apparent in this imagery does not coincide with the present use of this region. Roads and vestigial settlements appear which seem to be unrelated to present activities. The assumption can be made that many of these features are relict and bear little or no importance to the present cultural landscape. This study will attempt to isolate those features which are indeed relict and to explain their persistence on the landscape.

The methodology employed in the preparation of this report will include the interpretation of the Skylab and supporting aircraft imagery as well as necessary field work.

2.2.5 Yuha Desert Ecological Study

The Department of Earth Sciences of the University of California, Riverside and the Bureau of Land Management (BLM) office in Riverside have initiated a joint feasibility study in the Yuha Desert of Southern

California. The prupose of the study is to determine the value of Skylab and supporting aircraft imagery for delimiting ecotypes in the desert environment (soils-vegetation-slope). In January, 1974, the first ground reconnaissance will be begun by BLM researchers. Supplementary data interpreted from Skylab and aircraft imagery will be provided by the University of California. If such a study proves feasible, it will be expanded into the Mojave Desert, assuming additional Skylab imagery becomes available.

2.2.6 Big Bend Structural Anomaly

Perusal of Skylab imagery has revealed the presence of a geomorphic anomaly on the imagery. The anomaly is manifest as a semicircular pattern in rock structure. Initial impression of the feature is that it is a relict meander scar of the Colorado River. Examination of 15-minute quadrangles of the region and existing geologic maps indicate that the feature is Cambrian in origin, also the topography shows conformance with surrounding structural features. Future study of this anomaly will anlayze the feature's genesis.

2.2.7 Vertical Distribution of Vegetation in the Lanfair Valley/ New York Mountains Region of California

The purpose of this study is to assess vegetation responses to various environmental changes as indicated by altitudinal differences. These differences occur in the climatic, edaphic and hydrologic environments as altitude changes. By employing methodologies developed in the Yuha Desert Study (q.v.) and enhancing the available imagery through the technique of density slicing, an attempt will be made to isolate the various ecosystems as well as changes in the micro-environment.

2.3 WORK PLANNED DURING THE NEXT REPORTING PERIOD

Researchers at the Riverside campus will continue work on the studies reported in Section 2.2. Work initiated in the Owens Valley-Mojave Desert and Imperial-Coachella Trough will be expanded as additional Skylab imagery is received, in addition to exapnded research topics.

Attached is the Riverside campus milestone projection (Table 2.1).

TABLE 2.1. RIVERSIDE CAMPUS MILESTONE PROJECTION